International Journal of Civil, Structural,
Environmental and Infrastructure Engineering
Research and Development (IJCSEIERD)
ISSN(P): 2249-6866; ISSN(E): 2249-7978
Vol. 4, Issue 3, Jun 2014, 1-10
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ESTIMATION OF SHEAR STRENGTH PARAMETERS OF SOILS USING ANN TECHNIQUE

ABEER ABDULJABBAR ABDULABBAS & Y. K. BIND

Department of Civil Engineering (Geotechnical Engineering), Sam Higginbottom Institute of Agriculture Technology & Sciences, Deemed University, Allahabad, Uttar Pradesh, India

Republic of Iraq, Babylon University, Hillah, Iraq

ABSTRACT

The present study emphasizes on development of artificial neural network (ANN) models for prediction shear strength parameters like cohesion and angle of shearing resistance of the soil. Pertinent input parameters like depth, SPT- N value, liquid limit and plastic limit have been chosen for estimating two pertinent output parameters of shear strength. A total data sets of soil geotechnical investigation area were collected, out of which 72 datasets were from site A, Cohesion-less soils were not included for prediction of shear strength parameters. ANN models for each site were developed. First two models consist cohesion and angle of internal friction as output separately whereas third model consist both cohesion and angle of internal friction as output parameters.

In the ANN analyses, the data set is generally normalized to obtain better convergence, prior to the training stage, a certain range in which the inputs and targets values fall is determined. The normalized dataset was then used to train neural networks. At the end of analysis, the network outputs were post processed to convert the data back into non- normalized units. Some precautionary measures adopted during the development of the models were the separation of cohesion-less soil, selection of at least two or more than two pertinent input parameters and training each network several times for different iteration to avoid anomaly in result.

The results of ANN models were examined on the basis of mean square error and regression. Some of the pertinent input parameters were introduced in all networks to compare the result of actual and predicted output by the networks. Network error, percentage error, root mean square error and mean absolute error between calculated and predicted value for all networks were calculated. This indicate that ANN is a strong tool for predicting shear strength parameters of soil. The result of models showed the feasibility of ANN in geotechnical engineering.

KEYWORDS: Artificial Neural Network (ANN), Mean Square Error (MSE) and Regression, Root Mean Square Error (RMSE)

INTRODUCTION

One of the most important engineering properties of soil is its shear strength or ability to resist sliding along internal surfaces within a mass. The stability of cut, the slope of an earth dam, the foundation of structures, the natural slopes of hillsides and other structures built on soil depend upon the shearing resistance offered by the soil along the probable surface of slippage. There is hardly a problem in engineering which does not involve the shear properties of soil in some manner or other. The basic concept of friction is applicable to the soils which are purely granular in character. Soils, which are not purely granular, exhibit an additional strength which is due to cohesion between the particles.

It is therefore still customary to separate the shearing strengths of such soils into two components one due to cohesion between the soil particles and the other due to friction between them. Though there are lots of analytical solution. Empirical relationships and laboratory methods available to find out the shear strength parameters using these relationship and experiment, but these days artificial intelligence is playing an important role in the field of engineering, medical science, estimating, planning, credit evaluation, business and marketing etc. Artificial Neural Networks which works on the principle of biological neuron is one of those methods of artificial intelligence. ANN works by learning or training as human mind do.

Not only living being but also many devices are working on the principle of learning. May be we can ignore the significance of learning because it is intrinsic property of the mind and we don't need extra efforts to run/end this process but the truth is involved in the fact the we can solve numerous problem in different field by providing learning to the human mind or processors by any means. Artificial Neural Networks (ANN's) are based on the same concept of learning and generalizing from examples and experience to produce meaningful solutions to problems even when input data contain errors and are incomplete· An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous system, such as the brain, process information. The key element of this paradigm is the noble structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. In recent times, ANNs have been applied successfully to many prediction tasks in geotechnical engineering, as they have the ability to model nonlinear relationships between a set of input variables and corresponding outputs. A comprehensive list of the applications of ANNs in geotechnical engineering is given in subsequent unit. In the present study ANN models are used to predict the shear strength parameters i.e. cohesion 'c' and angle of internal friction 'φ' from combination of different input parameters for three different sites. Finally, a combine ANN model is developed by combining all the input data from all three sites to check the feasibility of ANN model. To avoid over fitting in ANN models the cross-validation technique (Stone 1974) was used. In this method the available data are divided into three sets; training, testing, and validation. The training set is used to adjust the connection weights. The validation set is used to check the performance of the network at various stages of learning, and training is stopped once the error starts increases. The testing set is used to evaluate the performance of the model only when training has been successfully accomplished. Feed forward back propagation neural network with activation function that is TanSig (X) for hidden layer and output layer selected to develop different models. The momentum term, learning rate and synaptic weight were kept adjustable. Statistical parameters MRMS, standard deviation, MSE and regression etc. were used to check the predicting ability of ANN models.

Objective

- To develop the ANN models for three sites individually.
- To develop the ANN model for combination of all three sites.
- To predict the shear strength parameters with various combination of inputs.
- To develop the ANN model for multidimensional output.
- To compare prediction models on the basis of statistical parameters

ARTIFICIAL NURAL NETWORK AN OVERVIEW

Recent development in the field of computer based modeling had provided an alternate over hectic and tedious work of developing analytical and computational models in the field of engineering and science, one of them is Artificial Neural Network based models which are not only capable of developing models but also contains predicting capacity. ANN works on the principle of biological neuron is a strong tool capable of learning the trends for particular set of input and target data. Artificial neural networks can be most adequately characterized as computational models with particular properties such as the ability to adapt or lean, to generalize, or to cluster or organize the data, and which operations based on parallel processing. Luerssen and Power in 1996 his paper 'On the Artificial Evolution of Neural Graph Grammars' credited artificial neural networks with biological plausibility.

Introduction of Artificial Neural Network

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNS, like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well.

Why Use Neural Networks?

Neural network, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. This expert can then be used to provide projections given new situations of interest and answer "what if" questions. Other advantages include:

- **Adaptive Learning:** An ability to learn how to do tasks based on the data given for training or initial experience.
- **Self - Organization:** An ANN can create its own organization or representation of the information it receives during learning time.
- **Real Time Operation:** ANN computation may be carried out in parallel, and special hardware devices are being designed and manufactured which take advantage of this capability.
- **Fault Tolerance via Redundant Information Coding**: Partial destruction of network leads to the corresponding degradation of performance. However, some network capabilities may be retained even with major network damage.

Human and Artificial Neurons-Investigating the Similarities

Much is still unknown about how the brain trains itself to process information, so theories abound. In the human brain, a typical neuron collects signals from other through a host of fine structures called dendrites. The neuron sends out spikes of electrical activity through a long, thin stand known as an axon, which splits into thousands of branches. At the end of each branch, a structure called a synapse converts the activity from the axon into electrical effects that inhibit

or excite activity from the axon into electrical effects that inhibit or excite activity in the connected neurons. When an neuron receives excitatory input that is sufficiently large compared with its inhibitory input, it sends a spike of electrical activity down its axon. Learning occurs by changing the effectiveness of the synapses so that the influences of one neuron on another changes.

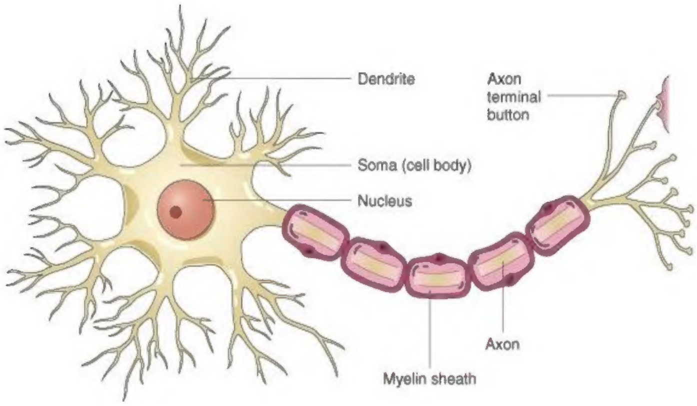

Figure 1: Neurobiological Background

ROM Human Neurons to Artificial Neurons

We conduct these neural networks by first trying to deuce the essential features of neurons and their interconnections. We then typically program a computer to simulate these feature. However because our knowledge of neurons is incomplete and our computing power is limited, our models are necessarily gross idealizations of real networks of neurons.

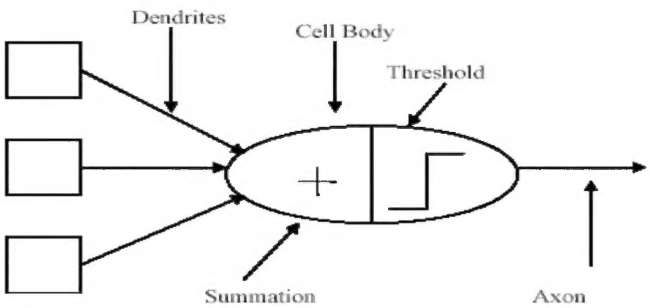

Figure 2: The Neuron Model

DEVELOPMENT OF ANN'S

In this present study six geotechnical parameters were selected locations from Allahabad city further these data were divided into input and target datasets. It was seen from these datasets that two types of soil in these particular zones were prevailing and these were the friction cohesive soil ($c > 0$, $\phi > 0$) and cohesion-less soil ($c = 0$, $\phi > 0$). As we know that the cohesion-less soil do not possess consistency characteristics (that is liquid limit and plastic limit) therefore cohesion-less soil was not included in the analysis. The potential geotechnical parameters were depth, SPT-N value, liquid limit, plastic limit and shear strength parameters that is 'c' and 'φ'. Out of six parameters four pertinent input selected were depth, SPT-N value, liquid limit and plastic limit remaining properties i.e., cohesion and angle of internal friction were selection as target data.

Table 1: List of Model Table

S. No.	Combinations	Input/Inputs	Target/Targets
1	M_7	W_L, $W_{p,}$ N & H	C
2	M_8	W_L, $W_{p,}$ N & H	φ

RESULTS AND DISCUSSIONS

The systematic study of different networks gave the following results.

Comparative Study of Individual Site Model No (M_7 N_{12})$_A$ for c

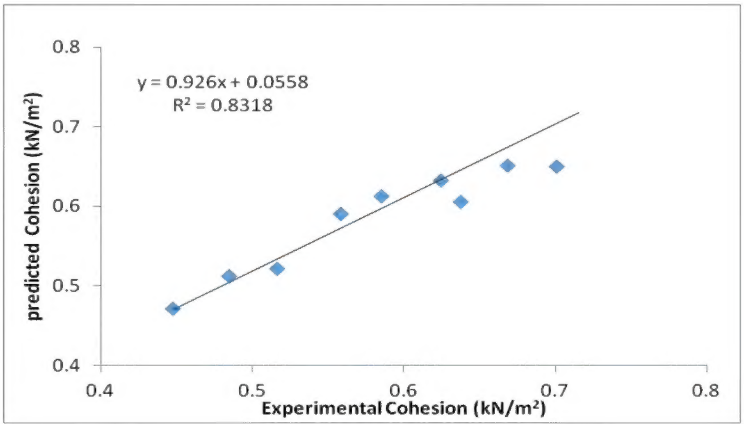

Figure 3: Comparative Study between Experimental and Predicted Value for Model No (M_7 N_{12})$_A$

The network architecture for model no. (M_7 N_{12})$_A$ is 4-6-3-1, which shows there are two hidden layers consisting six and three neurons. This network gave very close value of experimental and predicted output (cohesion). MSE and regression for this network wer0.0039716&0.86874respectively.

Table 2: Statistical Parameters for Model No (M_7 N_{12})$_A$

Sr. No.	Experimental Value	Predicted Value	Prediction Error	Error (Decimals)
1	0.7152	0.8033	-0.0881	-0.12318
2	0.6684	0.6521	0.0163	0.024387
3	0.6744	0.6321	0.0423	0.062722
4	0.6352	0.6232	0.012	0.018892
5	0.6245	0.6325	-0.008	-0.01281
6	0.6371	0.6059	0.0312	0.048972
7	0.7008	0.6507	0.0501	0.07149
8	0.6078	0.6314	-0.0236	-0.03883
9	0.6158	0.6224	-0.0066	-0.01072
10	0.6574	0.7021	-0.0447	-0.068
Mean of Errors				-0.00271

Table 3

	Min. Error (%)	Max. Error (%)	RMSE	MAE
Network Training Error	1.28	12.32	0.038612	- 0.01191

Comparative Study of Site Model No $(M_8N_{12})_A$ for Output 'φ'

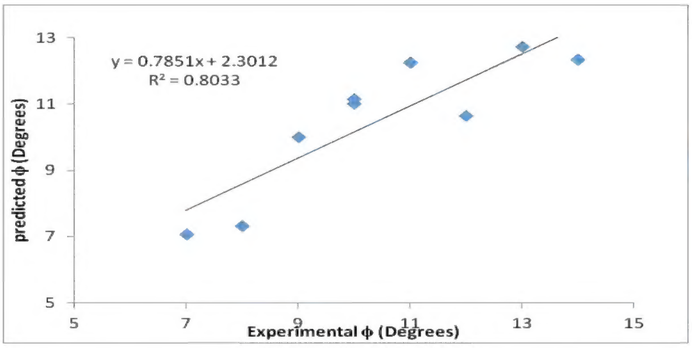

Figure 4: Comparative Study between Experimental and Predicted Value for Model No $(M_7\ N_{12})_A$

The network architecture for model no. $(M_8\ N_{12})_A$ is 4-6-3-1, which shows there are two hidden layers consisting six and three neurons. This network gave very close value of experimental and predicted output (Angle of internal friction). MSE and regression for this network were 0.002285 &0.94577 respectively.

Table 4: Statistical Parameters for Model No $(M_8\ N_{12})_A$

Sr. No.	Experimental Value	Predicted Value	Prediction Error	Error (Decimals)
1	11	12.25	-1.25	-0.11364
2	8	7.32	0.68	0.085
3	10	11.15	-1.15	-0.115
4	14	12.35	1.65	0.117857
5	13	12.74	0.26	0.02
6	9	10	-1	-0.11111
7	7	7.07	-0.07	-0.01
8	12	10.65	1.35	0.1125
9	10	11.02	-1.02	-0.102
10	14	13.25	0.75	0.053571
Mean of Errors				-0.00628

Table 5

	Min. Error (%)	Max. Error (%)	RMSE	MAE
Network Training Error	1.00	11.79	1.027998	0.02

CONCLUSIONS

The value of shear strength parameters cohesion (c) and angle of internal friction (φ) were predicted successfully for almost all the sites. The results indicate that back-propagation neural networks have the ability to predict the cohesion (c) for cohesive with an acceptable degree of accuracy

Whereas in combined model regression were very less for cohesion and angle of friction which shows that it is slightly difficult to obtain better results from multidimensional output system.

Study of network architecture of all models showed that either the combination of six neurons in second layer gave better results in comparison to models with other combination of neurons.

ANNs have the advantage that once the model is trained, it can be use as an accurate and quick tool for estimating the shear strength parameters without a need to perform any manual work such as using tables or charts. The main shortcomings of ANNs are the lack of theory to help with their development and their limited ability to explain the way they use the available information to arrive at a solution. In addition, like all empirical models, the range of applicability of ANNs is constrained by the data used in the model calibration phase and ANNs should thus be recalibrated as new data become available. However, despite the aforementioned limitations, the results of this study indicate that ANNs have a number of significant benefits that make them a powerful and practical tool for estimating shear strength parameters.

REFERENCES

1. K. Venkatesh, Yeetendra Kumar, Vijay Kumar, Prediction of shear strength parameters using artificial neural network technique. Proceedings, Technologia 2010, A National Conference, MPCCET, Bhilai, India.
2. Kurup PU, Dudani NK. Neural network for profiling stress history of clays from PCPT Data. J. Geotech. And Geoenvir. Engg 2002; 128(7):569-579.
3. Shahin MA, Maier HR. Jaksa MB. Data division for developing neural networks applied to geotechnical engineering. Journal of Computing in Civil Engineering 0887-3801 (2004)18:2(105).
4. Shahin MA, Maier HR, Jaksa MB. Predicting settlement of shallow foundations using neural networks. Journal of Geotechnical and Geoenvironmental Engineering 2002; 128(9): 785-793.
5. Al-Shayea NA. The combined effect of clay and moisture content on the behavior of remolded unsaturated soils. Engineering Geology 62 (2001) 319-342.
6. Estimation of soil compaction parameters by using statistical analyses and artificial neural networks "Gunaydin,O." Environmental Geology, Volume 57, Issue 1, pp.2003-215.
7. Cokca e, Erol o, and Armangil f. Effects of compaction moisture content on the shear strength of an unsaturated clay. Geotechnical and Geological Engineering 2004; 22:285-297.
8. Hettiarachchi H, Brown T. Use of SPT blow counts to estimate shear strength properties of soils: Energy balance approach. Journal of Geotechnical and Geoenvironmental Engineering 2009; 135(6):830-834
9. Basma AA, Kallas N, Modeling soil collapse by artificial neural network. Geotechnical and Geological Engineering 2004; 22: 427-438.
10. Sakellarious MG, Ferentinou MD. A Study of slope stability prediction using neural networks Geotechnical and Geological Engineering 2005; 23:419-445.
11. Shangguan Z, Li S, Luan M. Intelligent forecasting method for slope stability estimation by using probabilistic neural networks EJGE 2009 Vol. 13
12. Shang JQ, Ding W, Rowe RK, Soil characterization using complex permittivity and artificial neural network. Soils and foundations 2004; 44(5): 15-26
13. Kaya A. Residual and fully softened strength evaluation of soils using artificial neural networks. GeotechGeol (2009) 27:281-288

14. Gunaydm O. Estimation of soil compaction parameters by using statistical analyses and artificial neural networks Environ Geol (2009) 27:203-215
15. Su KY, Tak KB, Use of artificial neural networks in the prediction of Liquefaction Resistance of Sands. Journal of geotechnical and geoenvironmental engineering (2006) 11:1502-1504.
16. Shahin MA, Jaksa MB, Maier HR. Artificial neurl network – based settlement prediction formula for shallow foundations on granular soils. Australian Geomechanics September 2002.
17. Hanna AM, Ural D, Saygili G. Evaluation of liquefaction potential of soil deposits using artificial neural networks. Engineering Computations: International Journal for Computer-Aided Engineering and Software (2007) 24: 5-16
18. Toll D, Artificial Intelligence Systems for Geotechnical Engineering with specific reference to Ground Improvement 10th European Young Geotechnical Engineers' Conference Izmir, 21st-24th October 1996.
19. Ozer M, Isik NS, Orhan M. Statistical and neural network assessment of the compression index of clay-bearing soils. Bull EngGeol Environ (2008) 67:537-545.
20. EkremKalkan, SuatAkbulut, Ahmet Tortum and Samet Celik(29 October 2008) "Prediction of the unconfined compressive stredngth of compacted granular soils by using inference systems"
21. Shahin, M.A., Maier, H.R., and Jaksa, M.B. (2004b). "Data division for developing neural networks applied to geotechnical engineering." Journa of Computing in Civil Engineering, ASCE, 18(2), 105-114.
22. Shahin, M.A., Maier, H.R., and Jaksa, M. B. (2003d). "Settlement prediction of shallow foundations on granular soils using B-spline neurofuzzy models." Computers and Geotechnies, 30(8), 637-647.
23. Kingston, G. B., Maier, H. R., and Lambert, M.F. (2008). "Bayesian model selection applied to artificial neural networks used for water resources modeling." Water Resources Research, 44(W04419), doi: 10.1029/2007WR006155.
24. Kocjancic, R., and Zupan, J. (2000). "Modeling of the river flow rate: The influence of the training set selection." Chemometric and Inteligent Laboratory Systems, 54, 21-34.

AUTHOR'S DETAILS

Abeer Abduljabbar Abdulabbas Is work as a engineering in Babylon University, was born in Baghdad at July 1975, she received her B. Tech. from university of Tikrit / Civil Engineering department at 1998-Ministry of higher

education and scientific research, Republic of Iraq, she completed her M. Tech in Civil Engineering (Geotechnical Engineering) form Sam higginbottom Institute of Agriculture Technology & sciences, at 2014, Allahabad, U.P, India.

Yeetendra Kumar is working as Assistant Professor in the Department of Civil Engineering, Sam Higginbottom Institute of Agriculture, Technology and Sciences (SHIATS), Allahabad since February 2006. Author has completed his M. Tech in Civil Engineering with specialization in Geotechnical Engineering in the year 2005 from MNNIT, Allahabad. Author did B. Tech in Agricultural Engineering from SHIATS, Allahabad in the year 2002. His area of research is use of soft computing methods in Geotechnical Engineering. Author has published more than ten research papers in national and international conference and around ten papers in international journals. The personal details of author is given below